

Potential for a GNSS-based Determination of the Terrestrial Scale

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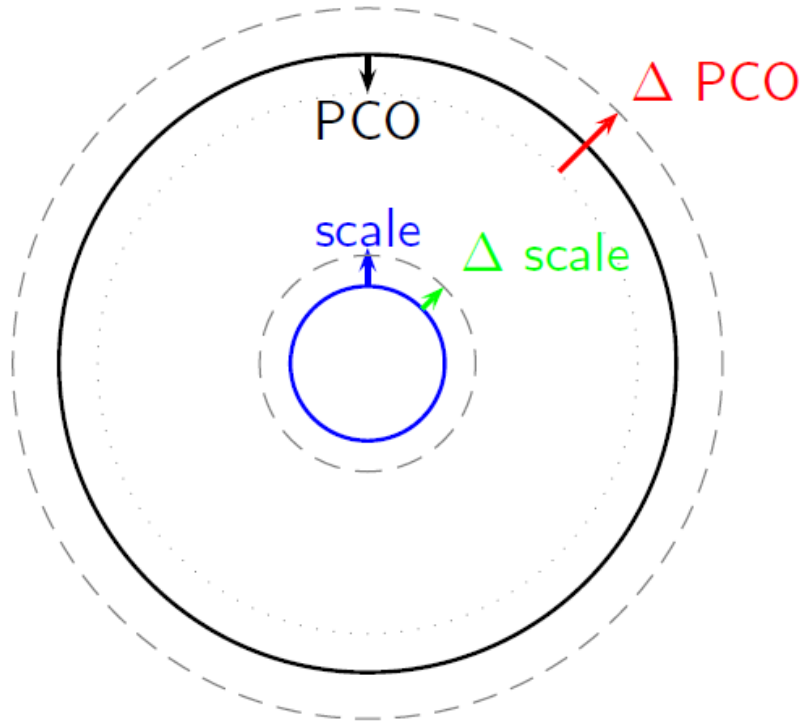
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10. July 2018, Montreal, Canada



Scale determination

Why do we need calibrated antennas?



- PCO to Scale:
[Zhu et al. 2002]
 $1\text{m} \hat{=} -7.8 \text{ ppb}$
 $1 \text{ ppb} \hat{=} -0.13 \text{ m}$
- PCO's: $-4 \text{ m } \Delta \text{ PCO}$
- Stations: 20 cm offset

Current status of antenna calibrations

Overview IGS14

GNSS	Frq	Sat.	Rob.
GPS	L1		
	L2		
	L5		
GLO	G1		
	G2		
	G3		
GAL	E1		L1
	E5a		L2
	E5b		
	E5		
	E6		

GNSS	Frq	Sat.	Rob.
BDS	B1		L1
	B2		L2
	B3		
QZSS	L1		
	L2		
	L5		

unknown	estimated	calibrated	guess
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Rob. : roboter calibrations

Current status of antenna calibrations

Overview chamber calibrations

GNSS	Frq	Sat.	Rob.	Cha.
GPS	L1			
	L2			
	L5			
GLO	G1			
	G2			
	G3			
GAL	E1		L1	
	E5a		L2	
	E5b			
	E5			
	E6			

Used for this study

GNSS	Frq	Sat.	Rob.	Cha.
BDS	B1		L1	
	B2		L2	
	B3			
QZSS	L1			
	L2			
	L5			

unknown	estimated	calibrated	approx.
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Rob. : roboter receiver antenna calibrations
Cha. : chamber receiver antenna calibrations

Reprocessing 3: will include multi-GNSS calibrations from roboter calibrations

- In June 2019 GSA released the chamber calibrated PV and PCO for the last 8 Galileo FOC satellites
 - **full constellation with calibrated PV and PCOs available!**
- Galileo shall be included into IGS reprocessing effort for the next ITRF solution:
 - What about the receiver antenna calibrations?
 - Are the estimated PCO for GPS and GLONASS compatible with the Galileo PCOs?
 - If not, how can we address this issue?
 - **Can we use Galileo to define a GNSS scale?**

Overview

- For the IGS AC Workshop 2019 dedicated test solutions were created to address those issues
- Based on:
 - **Chamber calibrated receiver antennas**
 - The final reprocessing will be based mainly on robot calibration provided by Geo++ and extended by chamber calibrations (they were not available at the time of the test solution)
- **Test solutions:**
 - **COD: 2017 / 2018 (GE, G, E)**
 - **ESA: 2017 / 2018 (GE, G, E)**

Chamber calibrated receiver antennas

TRF scale contribution from GNSS?

- Creation of type-mean antenna pattern from chamber calibrations (more than 250 individual calibrations) → 37 type-mean calibrations (covering ~49% of the IGS network)
- Differences between robot and chamber calibrations?
- Comparison of satellite PCO and scale determination using robot or chamber calibrated ground antennas

Case study:

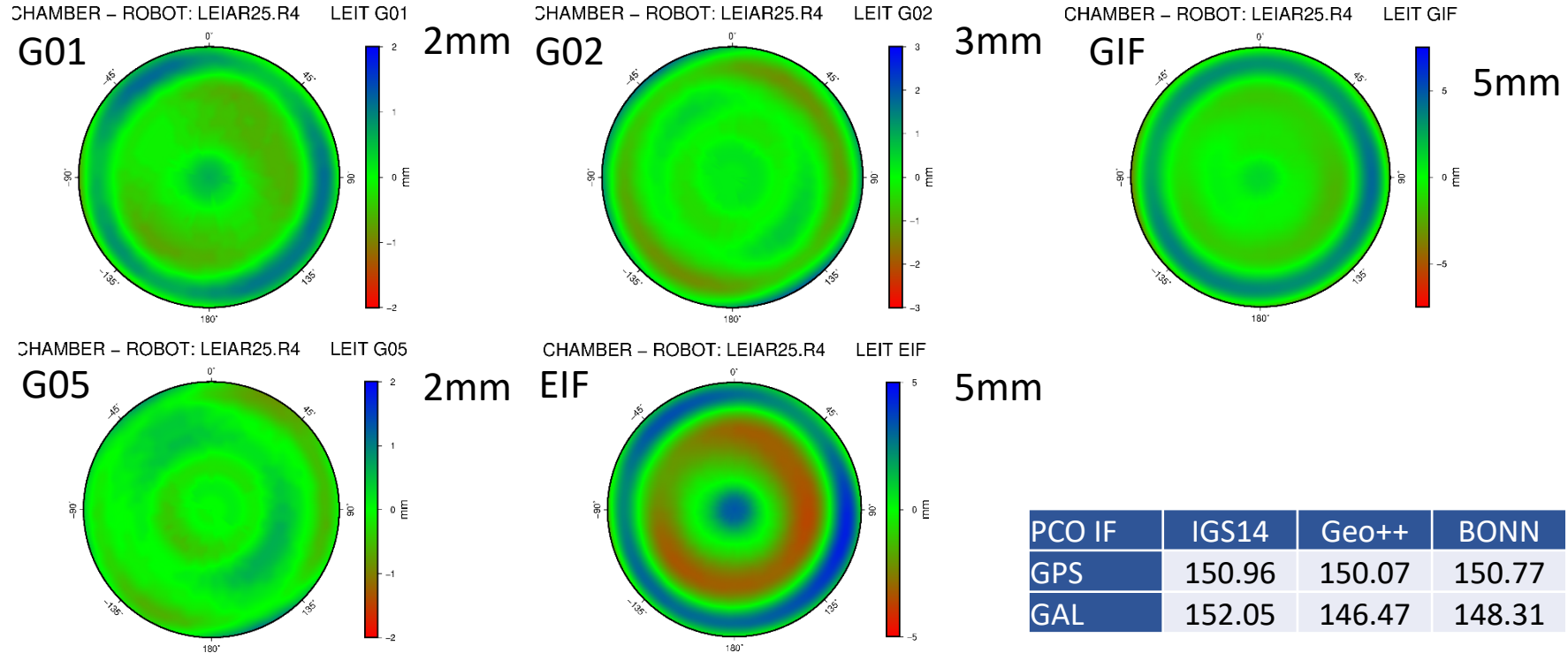
- Study on the scale determination using data from 2017-2018
- GPS/Galileo solution (COD / ESA)

Chamber vs. robot calibrations

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Comparison: GPS PV: BONN – Geo++

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Comparison receiver antenna PCOs

IF Galileo - GPS (PCO up [mm])

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		ETH Zürich ¹	IGS14 (L1/L2)	BONN
JAV_GRANT-G37	NONE	6.7	-1.3	
JAV_RINGANT_G3T	NONE	-10.6	+1.2	-7.6
SEPCHOKE_B3E6	SPKE	-8.0	+4.7	
TRM57971.00	NONE	-2.94	-1.7	-5.2
		Geo++	IGS14 (L1/L2)	BONN
LEIAR25.R4	LEIT	-3.6	1.09	-2.45

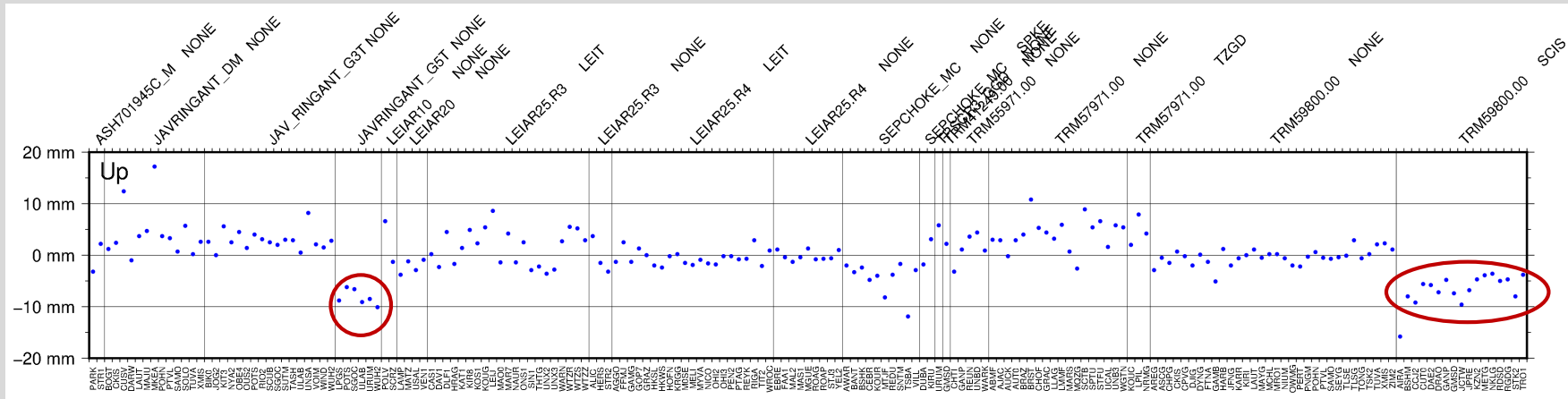
¹ [Willi et al. 2019, open access, <https://doi.org/10.3929/ethz-b-000332282>]

Consistency of antenna calibrations

Based on ESA solutions

Systematic errors between GPS and Galileo (E1/E5a) only solutions:

- Systematic differences for some receivers
- Robot calibrations have to be tested and, if needed, to be adjusted!



NB: The solutions were differenced after having brought them to a common origin, orientation and scale.

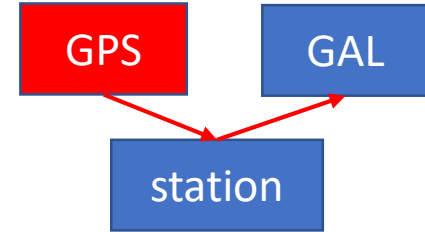
Station position differences are thus shown up to an unknown global translation, rotation and scale factor.

Scale study CODE (2017-2018)

PCO (system-wise, Z-component)

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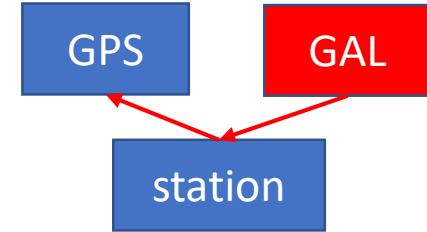
	Robot calibrations [cm]		Chamber calibrations [cm]	
	GPS	Galileo	GPS	Galileo
GPS PCO fixed	-	-0.2 ± 1.8	-	+24.7 ± 1.3

Scale study (2017-2018)

PCO (system-wise, Z-component)

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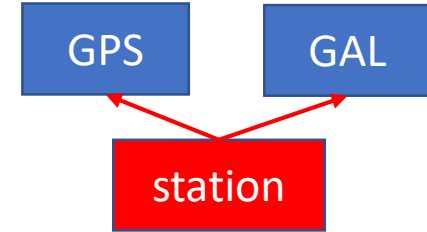
	Robot Calibration [cm]		Chamber Calibration [cm]	
	GPS	Galileo	GPS	Galileo
GPS PDO fixed	-	-0.2 ± 1.8	-	$+24.7 \pm 1.3$
Gal PCO fixed	-0.6 ± 2.5	-	-22.0 ± 2.1	-

Scale study (2017-2018)

PCO (system-wise, Z-component)

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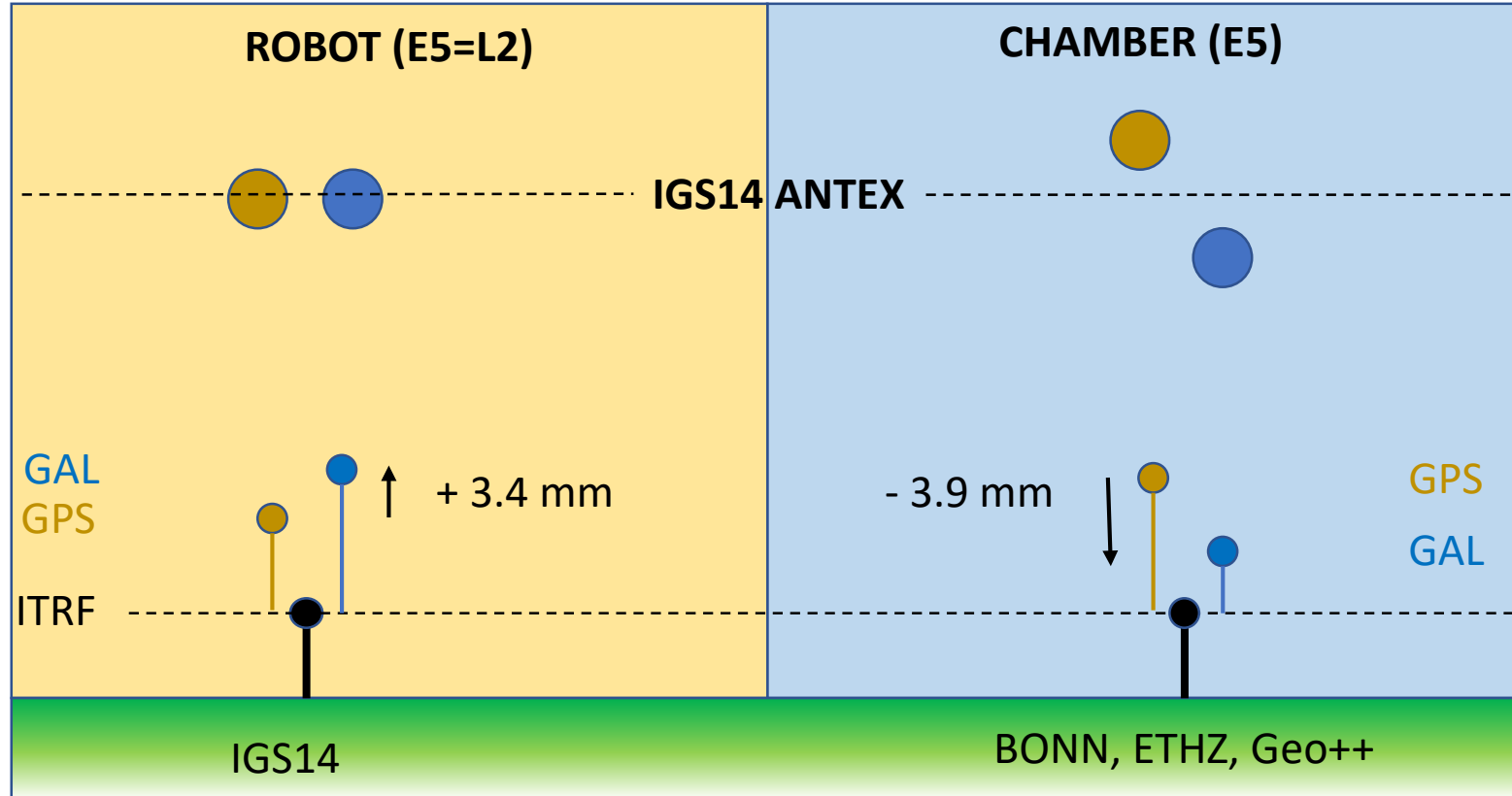
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GPS PCO fixed	-	-0.2 ± 1.8	-	$+24.7 \pm 1.3$
Gal PCO fixed	-0.6 ± 2.5	-	-22.0 ± 2.1	-
ITRF 2014 fixed	$+1.4 \pm 3.6$	$+1.9 \pm 4.7$	-10.9 ± 3.4	$+12.7 \pm 4.6$

Scale study (2017-2018)

Impact of IF-PCO values

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Scale study (2017-2018)

Scale w.r.t ITRF 2014 – GAL/GPS fixed

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Solution	IGS14 ANTEX	Chamber
GPS PCO fixed	2.58 mm	-3.00 mm
GALILEO PCO fixed	2.09 mm	7.27 mm
Difference GAL-GPS	+0.49 mm	+10.27 mm
	VLBI	SLR
ITRF 2014 ¹	+4.4 mm	-4.4 mm

1 ppb \cong 6.4 mm

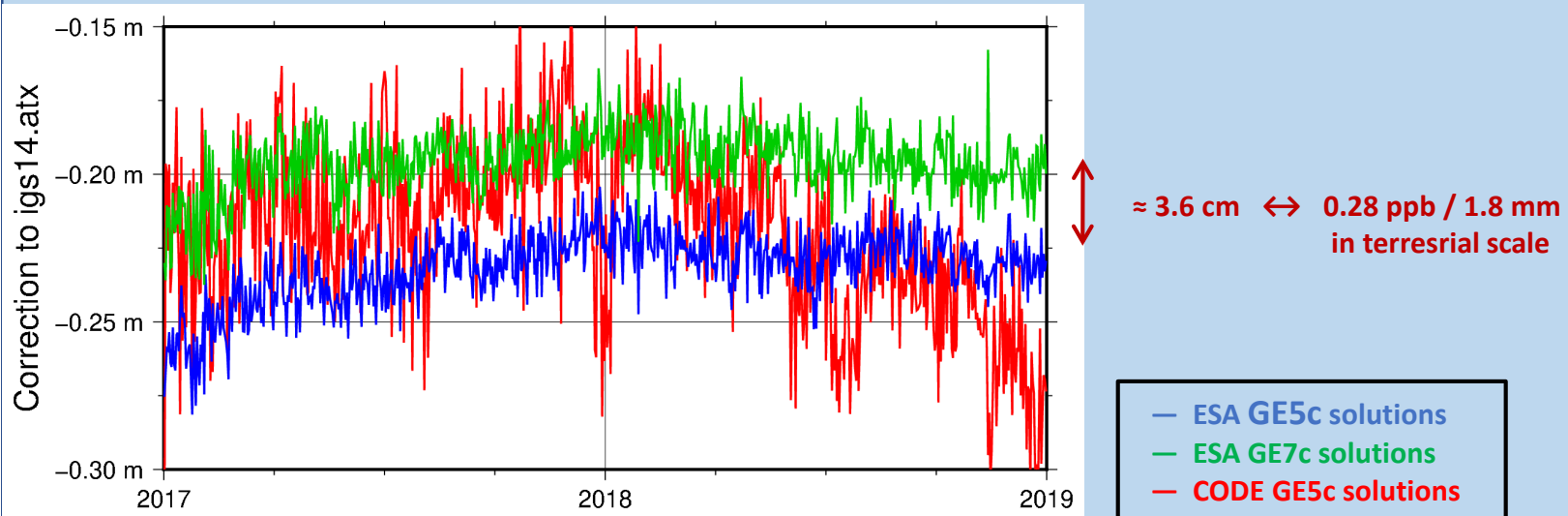
→ Chamber calibrations: scale of +4.7 mm (+7.3 with a priori value 0)

¹ [Altamimi et al. 2016, J. Geophys. Res.]

SINEX combination

ESA / COD (2017 & 2018)

Fix Galileo satellite z-PCOs; solve for an average correction to igs14.atx GPS satellite z-PCOs

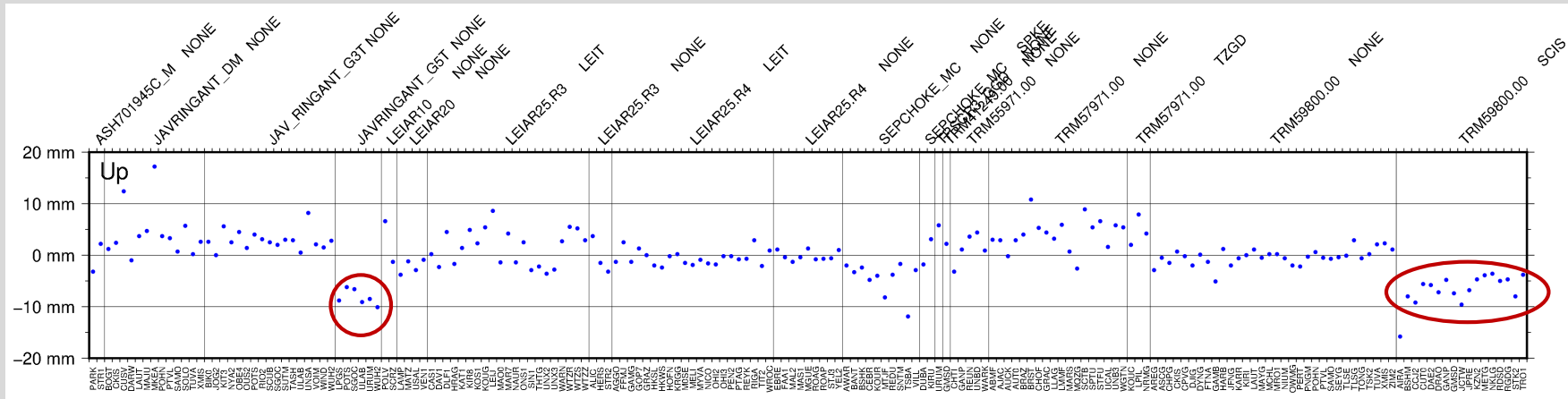


Consistency of antenna calibrations

Based on ESA solution

Systematic errors between GPS and Galileo (E1/E5a) only solutions:

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Calibrations:

- Reprocessing will be based mainly on robot calibrations
- Including E1/E5 calibrations
- Chamber calibrations for Galileo

Satellite PCO

- GPS/GLO PCO (z-component) rescaled to Galileo
- Based on SINEX combination from various AC contributions

Receiver PCO

- Comparison of GPS and Galileo only solutions
- Adjustment of PCO (z-component) if needed for Galileo